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Guidance on Applying the Data Quality Objectives Process for Ambient Air Monitoring Around Superfund Sites (Stage 3)

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Guidance On Applying The Data Quality Objectives Process For Ambient Air Monitoring Around Superfund Sites (Stage III)

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GUIDANCE ON APPLYING THE DATA QUALITY OBJECTIVES PROCESS FOR AMBIENT AIR MONITORING AROUND SUPERFUND SITES (STAGE III)

By

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PREFACE

This document, Guidance for Applying the Data Quality Objectives Process for Ambient Air Monitoring Around Superfund Sites (Stage III), along with a previous document (EPA-450/4-89-015, August 1989) covering Stages I and II, provides an illustration of how the data quality objectives (DQO) process is used to design an ambient air monitoring system that will be adequate for the intended use of the data. The two documents combined are intended to serve as a bridge between the Quality Assurance Management Staff's (QAMS') DQO guidance and an actual application of the DQO process at a Superfund site. This document illustrates the process of developing a monitoring system for volatile organic compounds in the ambient air to the point of submitting the design to the decision maker for approval. If the decision maker approves the design then a complete DQO document integrating a sampling and analysis plan, a quality assurance project plan, and a work plan can be prepared. Specifically, these documents were written to aid the Remedial Project Managers, On-site Coordinators, Enforcement Project Managers, and the EPA Regional and Superfund contractor personnel responsible for ambient air sampling and analysis at Superfund sites to carry out their jobs in an efficient and effective manner.

The DQO process as outlined by QAMS consists of three stages with several steps within each stage. In Stage I the decision maker (or ultimate data user) takes the lead role in stating the problem and defining the decision. The program and technical staff lead in establishing qualitative and quantitative constraints in Stage II. These first two stages of the process result in proposed DQOs with accompanying specifications and/or constraints. These DQOs and specifications are passed to the technical staff to complete Stage III; that is, to design a monitoring system which ensures that the DQOs will be met in an economical manner.

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SECTION 1.0
INTRODUCTION

1.1 PURPOSE AND SCOPE

This document reflects the nature of the sampling and analytical costs versus usable information decisions that must be made when initially developing a draft of a proposed air monitoring plan for subsequent approval by the ultimate decision maker, the remedial project manager (RPM) and/or the on-site coordinator (OSC). It addresses Stage III of the DQO process as a continuation of the DQOs and constraints developed in Stages I and II, the results of which were published as a separate report (1). In the DQO process, DQOs with quantitative and qualitative constraints are developed by the decision maker in consultation with the program and technical staffs. The results of Stages I and II are passed to the technical staff to design a monitoring system that will ensure that the DQOs will be satisfied under the constraints of manpower, instrumentation, facilities, and funds. The purpose of this document is only to illustrate the implementation of DQOs developed in Stages I and II. This involves the design of a data collection and analysis plan that will satisfy the DQOs as stated in Stages I and II. To complete the DQO process this data collection and analysis (or monitoring) design would be submitted to the decision maker for approval after which a detailed sampling and analysis plan including elements of a quality assurance project plan and a work plan could be developed.

This application is limited to monitoring volatile organic compounds in the ambient air around a hypothetical Superfund site. In a real application, consideration would be given to gaseous inorganic compounds and airborne particulate matter.

1.2 SUMMARY OF DQOs AND CONSTRAINTS

It is desirable that a user of this document have ready access to the preceding document that covers Stages I and II of the DQO process. For convenience of those readers who do not have the preceding document, however, it

is pointed out that many topics such as site description, waste characteristics, and available instrumentation are discussed in more detail in this document. Also, key points from Stages I and II such as the statement of the decision, actions to consider, ranking of errors by their seriousness, and the DQOs (presented as acceptable levels of false positives and false negatives) are restated here.

- statement of decision

  The decision to be made is whether or not action must be taken to protect the public from VOCs in ambient air during remedial response activities.

- actions to consider when a problem is identified

  Any of the following actions may be considered singularly or in combination with other actions:

  - institute controls to lower air emissions
  - halt remedial activity
  - evacuate the receptor population which is at risk
  - employ a more rigorous monitoring strategy

- ranking of decision errors by their seriousness

  - concluding there is a problem when the true concentration is well below the level which poses a health risk is a false positive error and the least serious.

  - concluding there is no problem when the true concentration is in the range associated with a health risk is a false negative error and is serious.

  - concluding there is no problem when the true concentration is in the range associated with immediate acute health problems is a false negative error and very serious.

- desired DQOs expressed as acceptable probabilities of false positive and false negative error rates at selected concentration levels

  The following statements of DQOs (or desired levels of performance) are given first as a general statement, then followed by a specific statement for benzene as an example. The permissible exposure limit (PEL) for benzene expressed as an 8-hour average is 1000 ppb (1 ppm). The level of concern specified by the decision maker for this Superfund site is 0.1 PEL, or 100 ppb.

false positive

- At a true average concentration of 1/2 the level of concern (1/10 PEL), the probability of a positive finding (that is, concluding that there is a problem) should be limited to 10% or less (the least serious error).

  For example, if the true benzene concentration is 50 ppb for an 8-hour average, there should be no more than a 10% chance of obtaining a measurement of 100 ppb or more.

false negatives

- When the true average concentration is 1.5 times the level of concern, the probability of a negative finding (that is, concluding that there is no problem) should be limited to 5% or less (the serious error).

  For example, if the true benzene concentration is 150 ppb for an 8-hour average, there should be no more than a 5% chance of obtaining a measurement of 100 ppb or less.

- When the true average concentration is 2 times either level of concern, the probability of a negative finding should be limited to 1% or less (the very serious error).

  For example, if the true benzene concentration is 200 ppb for an 8-hour average, there should be no more than 1% chance of obtaining a measurement of 100 ppb or less.

1.3 TECHNICAL APPROACH

This subsection presents an overview of the approach taken in designing a monitoring system for volatile organic compounds (VOCs) in ambient air for this Superfund site. While an effort was made to ensure reasonableness of the monitoring system design developed herein it is emphasized that the design only serves to illustrate the application of Stage III of the DQO process to this problem. Each phase of this approach is detailed in the sections that follow. First, to design an effective and efficient monitoring system, it was necessary to identify the compounds of interest and estimate their potential concentration levels at the point(s) of measurement. Because there were no applicable monitoring data on VOC concentrations in the ambient air during site remedial activity, site records were used to determine the RCRA waste codes represented in the buried drums. Each waste code description was used to identify individual VOCs in the waste. These VOCs were ranked according to

their vapor pressure, Henry's Law constant, and air toxicity (from Appendix A of the Superfund Public Health Evaluation Manual). Six of the most volatile and most toxic compounds were selected as indicator compounds.

Expected concentrations of these six compounds, relating to the distance from the work site, were generated using models for an "extreme-case" scenario and again for a more practical scenario. The extreme-case scenario assumed that several drums of waste were spilled, resulting in a pool of waste that was 7 meters by 7 meters and 1 centimeter deep; that the compound being modeled accounted for 50% of the waste (i.e., the concentration of the subject compound in the waste was 50%); and that the meteorological conditions were a temperature of 30°C and a wind speed of 12 m/s. For these conditions, an emissions model was used to provide estimates of 8-hour average emission rates for each VOC. These modeled 8-hour emission rates were used as inputs for a Gaussian diffusion model and the resulting 8-hour average concentrations at the distance of the closest receptor site were estimated.

This same procedure was carried out for a situation involving a volume of soil saturated with the liquid waste. As expected, the modeled 8-hour emission rates from saturated soil and resulting estimated ambient air concentrations were much less than those from the pool of waste. These modeling results were used as a guide for designing the monitoring system.

The objectives of this monitoring system are 1) to provide on-site (that is, near the work site), real-time or near real-time data of sufficient quality to allow for emission control actions to be implemented during the 8-hour work day (this would ensure that concentration levels of concern are not exceeded at receptor sites); and 2) to provide off-site measurements of 8-hour average concentrations at receptor sites to assure the decision maker that the DQOs were met for the subject sampling period and to provide real-time concentrations at receptor sites to allow timely application of emission control actions if there is an indication that VOCs are reaching the receptor site.

1.4 USE AND ORGANIZATION OF THIS DOCUMENT

This document attempts to present the thought process that the technical staff would follow in designing a monitoring system. To complete the DQO process the design would be submitted to the decision maker for approval after which the sampling and analysis plan including the quality assurance project

plan and work plan could be completed. The monitoring strategies, the decision criteria for initiating emissions control actions, and the criteria for deciding when to change strategies were based only on the information presented for this hypothetical site. Thus, these monitoring strategies and decision criteria are not to be assumed applicable to other sites without first going through the thought process using relevant site-specific information.

This document serves as an aid to the Remedial Project Managers, Enforcement Project Managers, and EPA Regional and Superfund contractor personnel responsible for ambient air sampling and analysis at Superfund sites. Its intent is to help these staff develop and apply site-specific DQOs for ambient air monitoring requirements at other Superfund sites.

It would be helpful if the reader is familiar with the following:

- Guidance on Applying the Data Quality Objectives Process for Ambient Air Monitoring around Superfund Sites (Stages I and II) (1)
- The QAMS guidance: Development of Data Quality Objectives, Description of Stages I and II (2)
- the four volumes of Procedures for Conducting Air Pathway Analyses for Superfund Applications (3,4,5,6)
- the two volumes by the Office of Solid Waste and Emergency Response: Data Quality Objectives for Remedial Response Activities (7,8)
- the two DQO papers prepared by OAQPS: Data Quality Objectives for the Toxic Air Monitoring Systems and Data Quality Objectives for the Urban Air Toxic Monitoring Program (9,10)

The remainder of the document is organized as follows. Section 2.0 gives a physical description of the Superfund site, its meteorological profile, and its waste characteristics. Since there were no VOC monitoring data available when the site was being disturbed during remedial activity, it was necessary to rely on emission and diffusion models to obtain some idea of the concentration levels to expect at the receptor sites for different scenarios at the work site. Section 3.0 discusses modeling results. Section 4.0 provides the process for selecting VOC instrumentation for this site. Section 5.0 presents and discusses the monitoring system design, including monitoring strategies and decision criteria. Section 6.0 gives an error analysis which indicates that the proposed monitoring system will satisfy the DQOs in terms of data quality.

SECTION 2.0
SITE DESCRIPTION

This section presents a more detailed description of the hypothetical Superfund site than was given in the document covering Stages I and II. The additional details include distances from the perimeter of the waste site to the different receptor sites, a meteorological profile for the site, and a discussion of waste characterization. These details were required as inputs to models for generating potential VOC concentrations downwind of the work site during remediation.

2.1 SITE DESCRIPTION AND RECEPTOR LOCATIONS

This hypothetical Superfund site, located on the outskirts of an urban area, consists of approximately 180 acres. The fenced-in site property is mostly flat, covered by weeds and brushes 1 to 2 meters in height. Also, there is a continuous row of both deciduous and nondeciduous trees ranging from 18 to 23 meters in height, just inside the boundary fence. Figure 1 is a scaled map of the site.

Site records indicate that approximately 20,000 drums containing waste from local industries were buried here from 1959 until 1980. Most of the drums were buried in a single layer at a depth of about 2 meters. The 3-acre area marked "A" in Figure 1 designates where the drums were buried. The drums contain mainly spent solvents representing RCRA waste codes F001 through F006.

Some of the drums have leaked and contamination of soil and groundwater is possible. This potential problem led to a Remedial Investigation/Feasibility Study (RI/FS) for the site. The remedial action selected following the RI/FS was to dig up the buried drums, pack them into larger drums labeled as containing hazardous waste, and transport them to a nearby hazardous waste facility. This remediation effort is expected to take 12 months of on-site activity based on an 8-hour, 5-day-a-week work schedule.

During the RI/FS, drums were disturbed and an unusual odor was detected at the house identified as receptor R1 in Figure 1. A measurement made with a total VOC instrument indicated that VOCs had been released into the air; therefore, monitoring will be necessary to detect any subsequent releases to the ambient air which would pose a threat to public health during remediation.

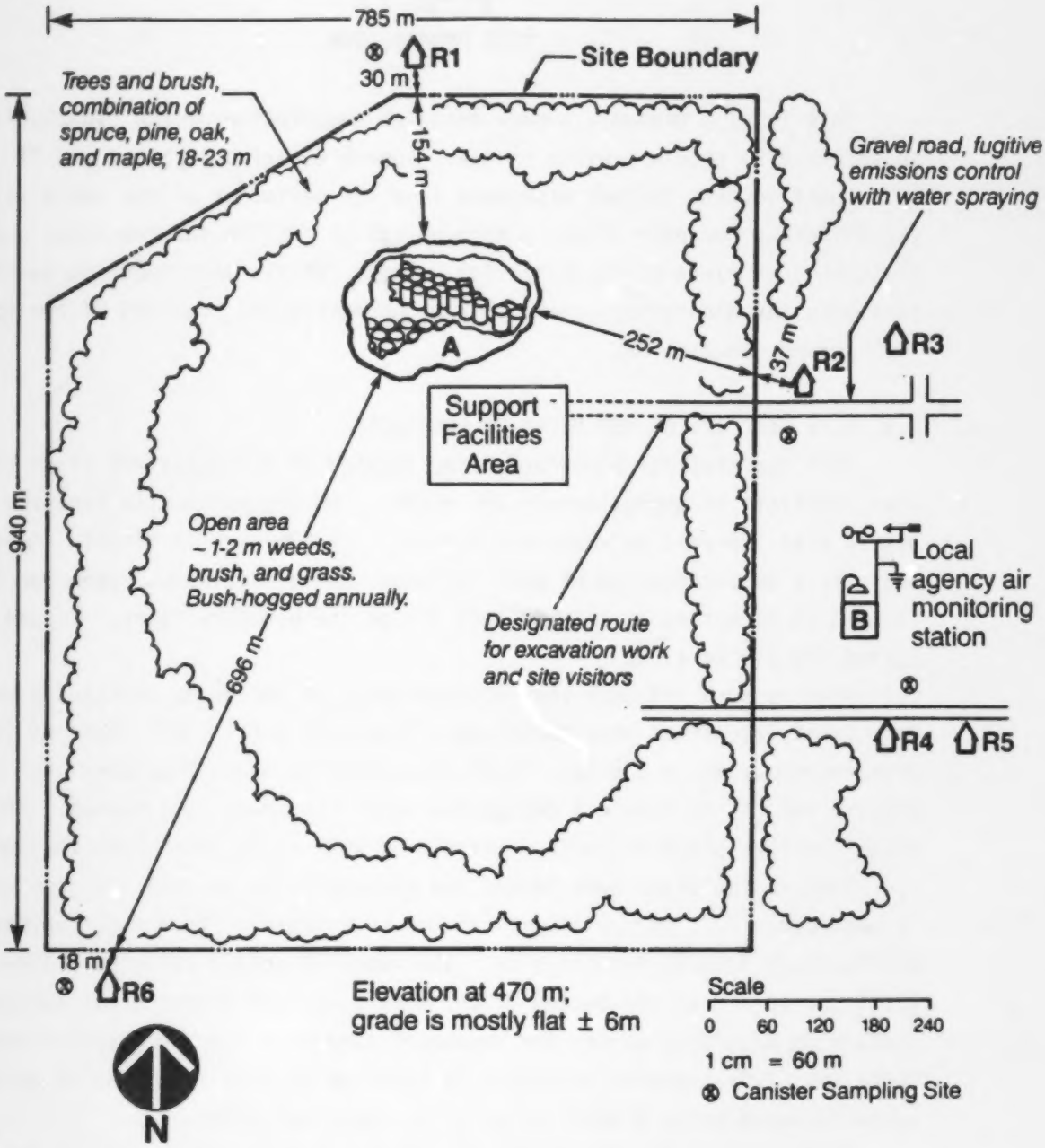

Figure 1. Hypothetical Superfund site with location of buried drums.

The guidance given in Procedures for Conducting Air Pathway Analyses for Superfund Applications, Volumes I and II will be followed in designing the ambient air quality monitoring system for this site.

The domain of interest consists of six houses located within 184 to 714 meters of the work site's perimeter (see Figure 1). The following information shows the bearing and distance to those receptors:

Receptor	Bearing (Degrees)	Distance from Boundary (Meters)
R1	358	184
R2	100	289
R3	93	390
R4	133	630
R5	128	660
R6	208	714

2.2 METEOROLOGICAL CONDITIONS

A State-operated air monitoring station has been operating for a number of years outside the fenceline of this site (see Figure 1). Its location adjacent to the site is coincidental, but historical meteorological data such as wind speed, wind direction, rainfall, and temperature will be useful in designing the monitoring network.

Because there are no applicable air monitoring data available, historical meteorological data are needed for two purposes: (1) to use in an emission rate model to assess the potential emissions, and (2) to model exposure risks, in terms of concentration levels, that may be experienced at receptor sites during remediation. Because the emission rates of volatile organic compounds are dependent upon temperature and wind speed, a knowledge of meteorological data that are representative of extreme cases is important. Table 1 represents the two-way distribution of wind speed and direction. Figure 2 is a graphical representation (a wind rose) of these wind speed and wind direction data. These historical meteorological data were generated at the State-operated air monitoring station. Table 1 lists the number of measured wind speed occurrences for each wind speed range and for each direction. For example, there were six occurrences of winds out of the south (S) at speeds between 3.1 and 4.4 meters per second (m/s). For modeling purposes, the data were reviewed to obtain a wind speed value that would represent an extreme-

TABLE 1. TWO-WAY FREQUENCY DISTRIBUTION
OF WIND SPEED AND DIRECTION

Speed (m/s)	Direction								
	S	SW	W	NW	N	NE	E	SE	Σ
1.8 - 3.0		1	2				1		4
3.1 - 4.4	6	16	2	8	13		17	2	64
4.5 - 5.8	11	16	5	12	8	4	15	7	78
5.9 - 7.1	11	21	10	16	7	14	6	2	87
7.2 - 8.4	5	8	9	8	1	22	5	5	63
8.5 - 9.8	1	8	6	5		37	1		58
9.9 - 11.1		2	5	1		26	2	1	37
11.2 - 12.5		2	4			11			17
12.6 - 13.8	1		4	1		14		2	22
13.9 - 15.2			2			4			6
15.3 - 16.5		2	1						3
16.6 - 17.8						5			5
17.9 - 19.2						1			1
	35	76	50	51	29	138	47	19	445

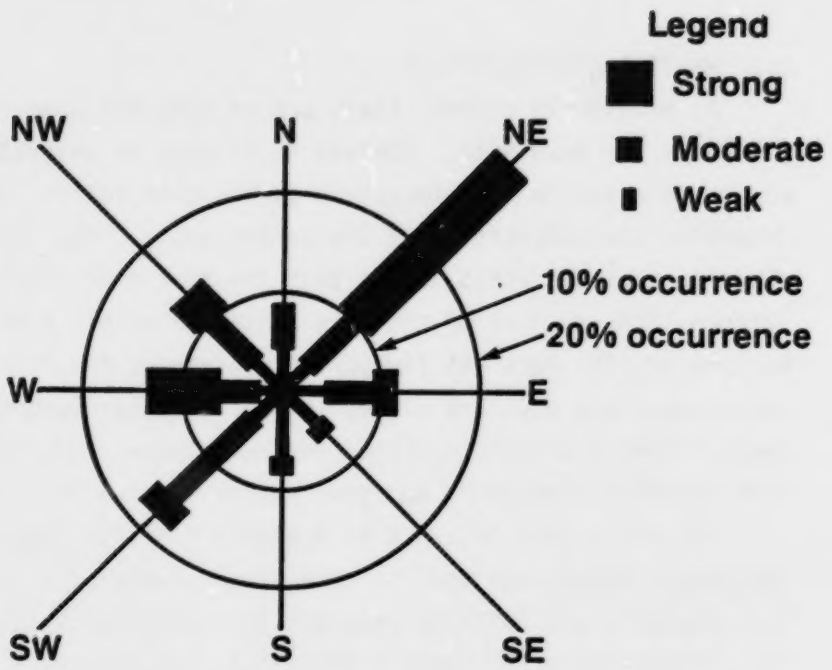

Figure 2. Wind rose of wind speed and wind direction data.

case situation. Numbers in Table 1 under the column headed "Σ" show that of a total of 445 occurrences recorded, 408 (slightly over 90% of the occurrences) were for wind speeds of 12.5 m/s or less. Thus, a value of 12 m/s was used to represent an extreme case for modeling purposes. Figure 3 shows that site temperatures of 30°C or greater are experienced only in the summer months, with the highest temperature of 37°C occurring in July. For modeling, a value of 30°C was used to represent an extreme case.

2.3 WASTE CHARACTERIZATION

As previously stated, there are no compound-specific air monitoring data available for this site. Therefore, to gain an understanding of which VOCs may be released to the atmosphere during remediation, it was necessary to determine the composition of the buried waste. The first step was to review the site records, which showed that the site contained waste codes F001 through F006. A list of the VOCs contained within each waste code was obtained from 40 CFR, Part 261 (subpart D, paragraph 261.31 of Table 1). These RCRA waste codes and VOCs are listed in the first two columns of Table 2. As shown, there are 30 VOCs listed for waste codes F001 through F005. Waste code F006 contains inorganics and does not enter into this illustration.

For those VOCs in Table 2, Appendix A of the Superfund Public Health Evaluation Manual was used to obtain each compound's vapor pressure, Henry's Law constant, air toxicity constant for carcinogens, and air toxicity constant for noncarcinogens (columns 4 through 7, respectively). These data were used for two purposes. First, a compound's volatility is a function of its vapor pressure and Henry's Law constant. Therefore, both vapor pressure and Henry's Law constant were used as inputs to the model for determining emission rates. Second, data from these columns (4 through 7) were used to rank the compounds according to their volatility (vapor pressure or Henry's Law constant) and their toxicity (carcinogen or noncarcinogen) to select six as indicator compounds. Ideally, these six indicator compounds would be both highly toxic and highly volatile. For example, benzene was one of the compounds selected. Table 2 shows that benzene had the 5th highest vapor pressure, the 8th highest Henry's Law constant, and the 5th highest air toxicity constant for noncarcinogens. It is obvious from the table that there are a lot of missing data; thus, in each individual case, professional judgement should be used to add or

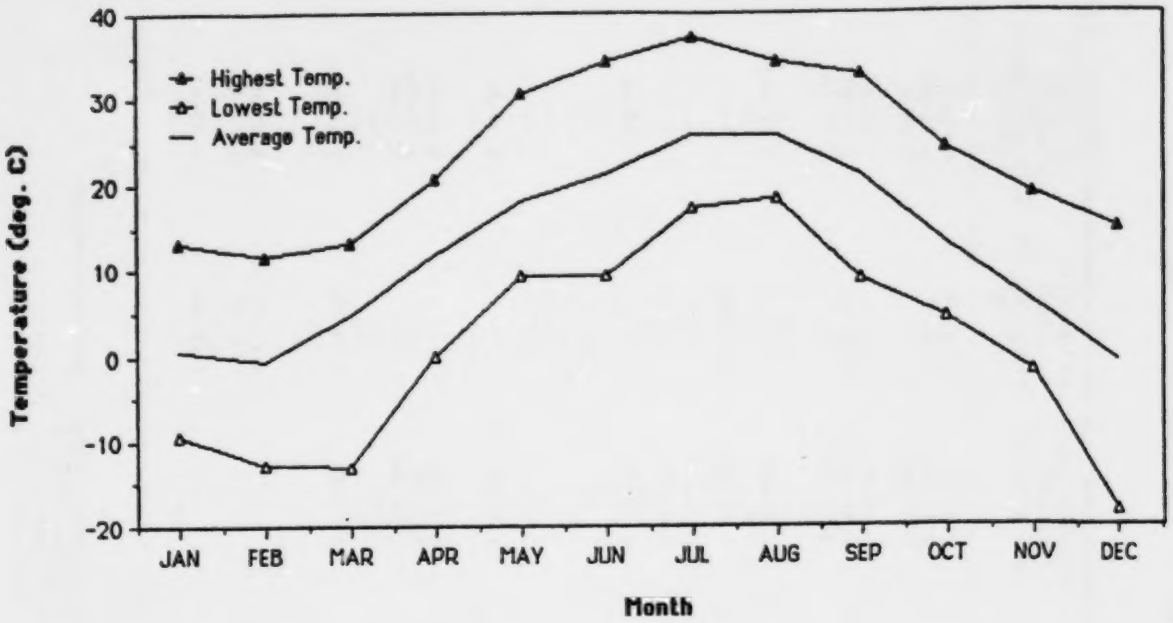

Figure 3. Temperature profile of the hypothetical Superfund site.

TABLE 2. CHARACTERISTICS OF COMPOUNDS AT THE SITE

RCRA CODE	COMPOUNDS	CAS NUMBER	VAPOR PRESSURE (mm Hg)[a]	HENRY'S LAW CONSTANT (atm m^3/mol)[a]	AIR TOXICITY CONSTANT (carcinogenic) (m^3/mg)[b]	AIR TOXICITY CONSTANT (non-carcinogenic) (m^3/mg)[c]	TOTAL VOC CONCENTRATIONS IN DRUMS (%)
F001, F002	Tetrachloroethylene	127-18-4	1.78+01	2.59-02	8.86-02	2.75-02	63.5
	Trichloroethylene	79-01-6	5.79+01	9.10-03	4.29-02	2.96+01	(F001)
	Dichloromethane Methylene chloride	75-09-2	3.62+02	2.03-03	---	9.2-03	
	1,1,1-Trichloroethane	71-55-6	1.23+02	1.44-02	---	7.33-03	90
	Carbon tetrachloride	56-23-5	9.00+01	2.41-02	1.88-01	3.17+00	(F002)
	Chlorobenzene	108-90-7	1.17+01	3.72-03	---	2.79-01	
	1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	2.70+02	---	---	---	
	o-Dichlorobenzene	95-50-1	1.00+00	1.93-03	---	3.61-01	
	Trichlorofluoromethane	75-69-4	6.67+02	---	---	---	
	1,1,2-Trichloroethane	79-00-5	3.00+01	1.17-03	1.03-01	---	
F003	Xylenes	---	1.00+01	---	---	---	75
	Acetone	67-64-1	2.70+02	2.00-05	---	---	
	Ethyl acetate	141-78-6	---	---	---	---	
	Ethyl benzene	100-41-4	7.00+00	6.43-03	---	1.10-01	
	Ethyl ether	---	---	---	---	---	
	Methyl isobutyl ketone	108-10-1	---	---	---	---	
	n-Butyl alcohol	71-36-3	---	---	---	---	
	Cyclohexanone	---	---	---	---	---	
	Methanol	67-56-1	---	---	---	---	
F004	Cresols & cresylic acid	1319-77-3	2.40-01	1.10-06	---	5.97+01	50
	Nitrobenzene	98-95-3	1.50-01	---	---	---	
F005	Toluene	108-88-3	2.81+01	6.37-03	---	5.20-02	42.5
	Methyl ethyl ketone	78-93-3	7.75+01	2.74-05	---	7.75-02	
	Carbon disulfide	75-15-0	3.00+02	1.23-02	---	4.24+00	
	Isobutanol	78-83-1	---	---	---	---	
	Pyridine	110-86-1	2.00+01	---	---	---	
	Benzene	71-43-2	9.52+01	5.59-03	7.71-02	1.10+02	
	2-Ethoxy ethanol	---	---	---	---	---	
	2-Nitropropane	---	---	---	---	---	
F006	Cadmium	7740-43-9	0	---	1.65+01	3.59+02	1[d]
	Chromium^{+6}	7740-47-3	0	---	1.11+02	2.50+01	100[d]
	Chromium - total	7740-47-3	0	---	---	---	100[d]
	Nickel	7440-02-0	0	---	2.85+00	1.57+02	500[d]
	Cyanide	57-12-5	Varies	---	---	---	100[d]

NOTE: Values are in scientific notation; ----indicates missing data.

a From Appendix A, Exhibit A-1 of EPA's Superfund Public Health Evaluation Manual. EPA/540/1-86/060
b From Appendix A, Exhibit A-3, Toxicity Data for Potential Carcinogenic Effects.
c From Appendix A, Exhibit A-5, Toxicity Data for Noncarcinogenic Effects (Note: Toxicity constants for carcinogens should not be compared with toxicity constants for noncarcinogens).
d Units are ppm, and not percent

remove compounds from the list of indicators as monitoring data become available. The six indicator compounds selected for this site are given in Table 3, along with permissible exposure limits (PELs) representing 8-hour averages and short-term exposure limits (STELs) representing 15-minute averages. Modeling for potential VOC concentrations at receptor sites will be limited to these six compounds.

An additional piece of information needed in order to model emission rates is an estimate of the VOC concentration in the waste; for example, what percent of the waste is benzene. The estimated total VOC concentrations in the waste drums (except F004) were taken from results of a random sample of responses to the National Survey of Hazardous Waste Generators (conducted for the EPA by Research Triangle Institute, 1987). Due to the lack of reported generator data for F004, characterizations for this waste code found in the RCRA Risk-Cost Analysis Model, Appendix A: Waste Stream Data Base (prepared for the EPA Office of Solid Waste, by ICF Corporation, March 1984) were used instead. The last column in Table 2 contains the estimated total VOC concentrations by waste code. These estimates range from 42.5% (F005) to 90% (F002). Based on these data, a concentration of 50% for an individual compound was used as an extreme-case for modeling. Note again that this exercise was necessary only because there were no applicable monitoring data available.

TABLE 3. EXPOSURE LIMITS FOR SELECTED INDICATOR COMPOUNDS

Compound	Permissible Exposure Limit (PEL)	Short-Term Exposure Limit (STEL)
Benzene	1 ppm for 8-hour time-weighted average	5 ppm for 15 minutes[a]
Trichloroethylene	50 ppm for 8-hour time-weighted average	200 ppm for 15 minutes[b]
Carbon tetrachloride	2 ppm for 8-hour time-weighted average	------
1,1,2-Trichloroethane	10 ppm for 8-hour time-weighted average	------
Carbon disulfide	4 ppm for 8-hour time-weighted average	12 ppm for 15 minutes[b]
Methyl ethyl ketone	200 ppm for 8-hour time-weighted average	300 ppm for 15 minutes[b]

ppm = parts per million

[a] 29 Code of Federal Regulations 1910.1028, Subpart Z.

[b] Federal Register, 54, Thursday, January 19, 1989, pages 2332-2983.

----indicates no short-term exposure limit.

SECTION 3.0
MODELING VOC CONCENTRATIONS

3.1 NEED FOR MODELING DATA

There are no ambient air concentrations available for this site to represent the remedial activities. For this reason, models were used for the single purpose of estimating potential risk to residents of the nearby houses. Specifically, what are judged to be the two extreme-case scenarios that could occur during remediation were modeled to provide estimates of the 8-hour average concentrations that would occur at the receptor closest to the work site. These scenarios were provided by the technical staff responsible for designing the monitoring network.

This modeling required the efforts of experienced modelers with necessary information on compound characteristics, meteorological conditions, and the scenarios. These models are reasonably complex, hence a detailed discussion is not attempted in this document. References to documents containing detailed information on the models are provided, however.

3.2 APPROACH FOR MODELING

Modeling was carried out in two steps. First, emission rates for the six indicator compounds were modeled for two extreme-case scenarios. These modeled emission rates were then used as inputs to a diffusion model to predict compound concentrations in the ambient air at the nearest receptor site.

The two scenarios selected to approximate extreme-case conditions follow:

- A waste spill emptying two 55-gallon drums, resulting in a liquid pool 7 meters by 7 meters and 1 centimeter deep. Fifty percent of the liquid waste was assumed to consist of the compound being modeled (for example, when modeling benzene, it was assumed that 50% of the waste was benzene). Meteorological conditions used were a wind speed of 12 m/s and a temperature of 30°C.

- Uncovering or working in an area 7 meters by 7 meters of soil saturated with liquid waste. As above, the compound being modeled was assumed to account for 50% of the liquid waste. A wind speed of 12 m/s and a temperature of 30°C were used for modeling.

3.3 MODELED EMISSION RATES

The modelers followed the guidance provided in the EPA document, Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF) - Air Emission Models (11). Inputs to the model included the compound's vapor pressure and Henry's Law constant (both obtained from Table 2, Section 2.0); wind speed; wind direction; and temperature, all taken to approximate extreme-case conditions from Section 2.0. The final equation giving the average emission rate for the compound follows:

$$Q = f_{air}\ V\ C_o/t$$

where Q = Average emission rate over time period t, grams per second (g/s).

f_{air} = The fraction of the compound originally in the waste, emitted to the air during time t.

Note: = f_{air} was modeled by a complex exponential function requiring input values on waste and compound characteristics and atmospheric conditions.

C_o = Initial concentration of the individual VOC in the liquid waste, g/m^3

V = Volume of liquid waste in the pool, m^3

The 8-hour emission rates in grams per second (g/s) for the six indicator compounds for the pool and saturated soil are given in Table 4.

TABLE 4. MODELED 8-HOUR AVERAGE EMISSION RATES

Compound	Emission Rate for Pool (g/s)	Emission Rate for Saturated Soil (g/s)
Benzene	8	1.1
Carbon Disulfide	8	0.7
Carbon Tetrachloride	8	0.7
Methyl Ethyl Ketone	8	0.7
Trichloroethylene	8	0.5
1,1,2-Trichloroethane	8	0.3

Modeling results for the waste spill pool were plotted to provide profiles of emission rate as a function of time over an 8-hour period for each of the six indicator compounds in Figure 4. Moving from left to right, the plotted points for emission rates are a 15-minute average, a 1-hour average, a 4-hour average, and, at the far right of the figure, an 8-hour average. For example, the figure shows that carbon disulfide had the highest average emission rate of all six indicator compounds for the first 15 minutes after the spill. (This was expected since carbon disulfide has the highest vapor pressure of the indicator compounds.) The 1-hour average emission rate for carbon disulfide was approximately 70 g/s, or about 1/4 of the 15 minute average of 275 g/s. This shows that nearly all of the carbon disulfide originally in the waste was emitted into the atmosphere the first 15 minutes after the spill. Average emission rates for 4 hours and 8 hours were the same for all six indicator compounds. Carbon tetrachloride, benzene, and methyl ethyl ketone also showed high emission rates within minutes after the spill. This rapid emittance of at least four of the six indicator compounds indicates that the site safety plan should specify level B protective clothing during all drum excavations. Time will not allow the crew to put on protective clothing or the monitoring staff to start up a monitoring system after a spill has occurred. This rapid emittance also indicates that, to capture the short-term high compound concentration levels resulting from a spill, the monitoring system must be set up and collecting a sample over the 8-hour work day. Also, a real-time or near real-time monitoring capability should be in place at the impacted receptor site to assess short-term exposure and to allow for timely application of emission control actions.

Emission rate results from modeling the saturated soil scenario were plotted similarly in Figure 5. Note that the emission rates from soil have approximately the same profile over time as emissions from the pool. The average 8-hour emission rates from soil are less by factors ranging from 7 to 27 than those from the pool, as seen in Table 4.

3.4 MODELED COMPOUND CONCENTRATIONS

A Gaussian dispersion model, based on the work of Turner (12), was used to estimate 8-hour average concentrations of the six indicator compounds at the nearest receptor (R1). Wind rose and temperature data presented in

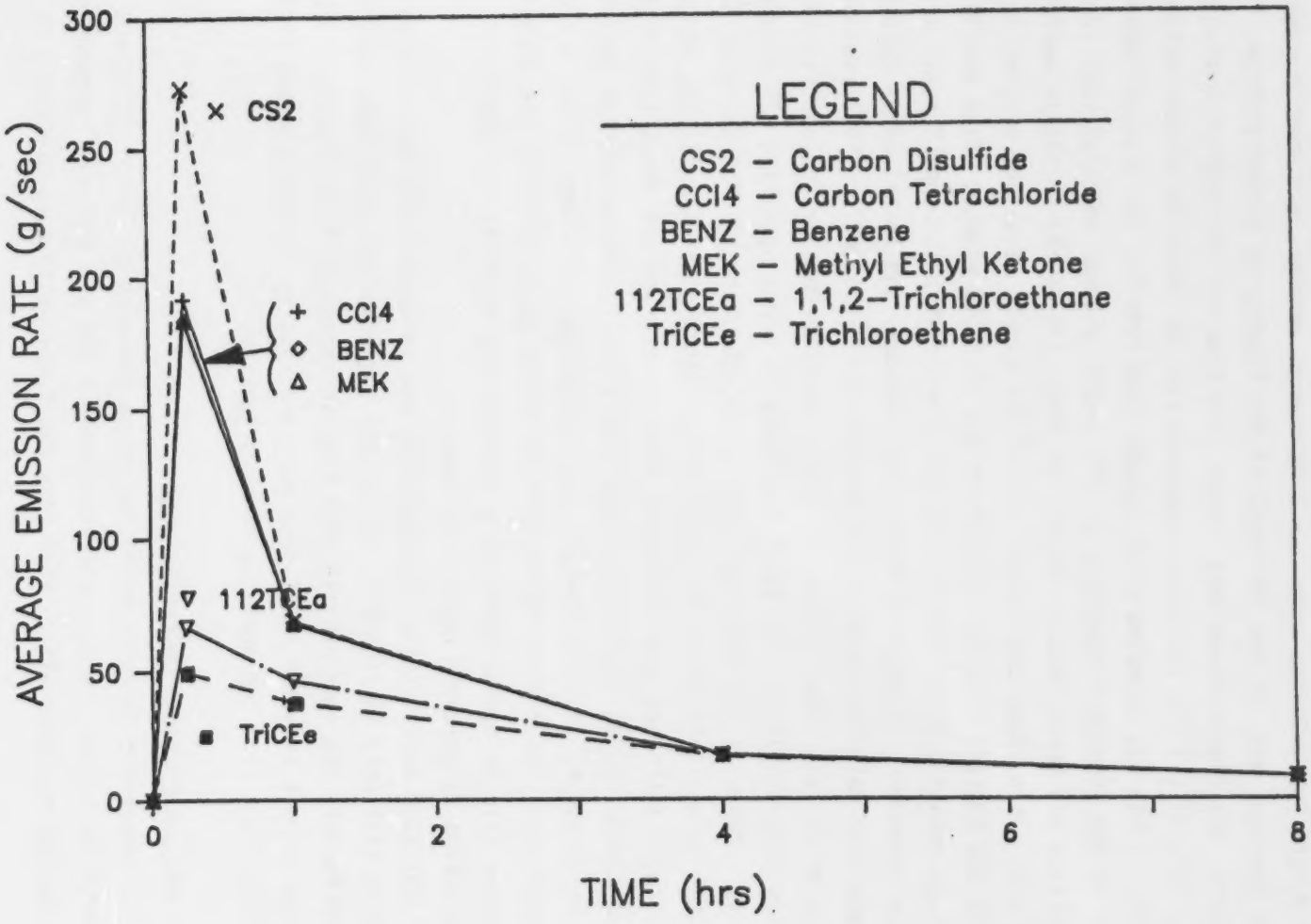

Figure 4. Average emission rates over time for an open spill (pool) of waste containing volatile compounds at concentrations of 50 percent each.

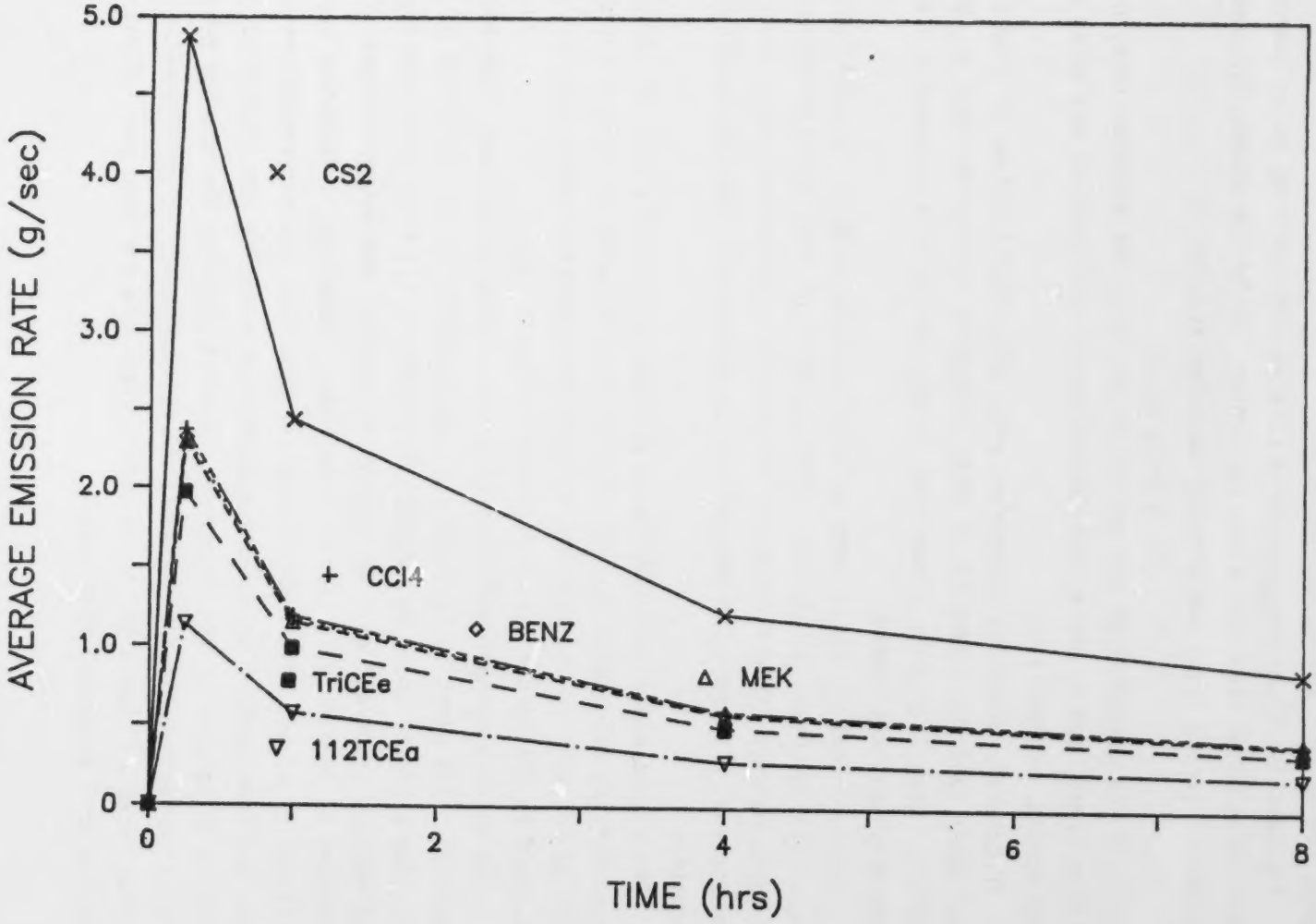

Figure 5. Average emission rates for newly unearthed soil contaminated near saturation with waste containing volatile compounds at concentrations of 50 percent each.

Section 2.0 suggested a combination of a wind speed of 12 m/s and a temperature of 30°C for an extreme case.

The Gaussian plume equation for a continuously emitting point source with no effective plume rise, but along the center line of the plume, for concentrations at ground level and directly downwind is given by

$$C = Q/(\pi \sigma_y \sigma_z u)$$

where C is the ground-level air concentration, Q is the emission rate, u is the wind speed, and σ_y and σ_z are the horizontal and vertical variances of plume spread, respectively.

In general, stability categories were identified in terms of wind speed, cloud cover, and the intensity of solar radiation (during the day) at the site location. Stability class C was used in this analysis in accordance with the above-mentioned wind speed.

The variances σ_y and σ_z were calculated using formulas recommended by Briggs (13) for urban conditions. Urban conditions were selected because of the trees between the work site and the receptors (see Figure 2). These formulas are valid for distances of 100 to 1000 meters from the source to the receptor.

The simple model described above provides a quick estimate of the ground concentrations using data for this Superfund site; however, more accurate and detailed analyses can be provided using higher accuracy models such as those described in EPA guidelines on air quality models (14).

The meteorological conditions of a site should be reviewed from two perspectives. The first is to model the concentration at the receptors of concern (the closest) under an extreme-case scenario (in high wind velocity and high ambient temperature). The second is to model the concentrations at the receptors of concern under actual conditions. Modeling is dependent upon the availability of sufficient meteorological data that are representative of the site, and upon whether or not the extreme-case modeling has identified concentrations of concern at the receptors. Table 5 contains the modeled 8-hour average concentrations for the six indicator compounds at the distance to the closest receptor, based on the emission rates from the open pool of waste and from the soil saturated with waste.

TABLE 5. MODELED 8-HOUR AVERAGE CONCENTRATIONS AT RECEPTOR 1

Compound	Concentration from Pool (ppb)	Concentration from Saturated Soil (ppb)	Level of Concern 0.1 PEL (ppb)
Benzene	40	2	100
Carbon Disulfide	40	4	400
Carbon Tetrachloride	40	2	200
Methyl Ethyl Ketone	40	2	20000
Trichloroethylene	40	2	5000
1,1,2-Trichloroethane	40	1	1000

The results of the modeling identified benzene as the compound posing the greatest health risk for residents at receptor R1. For results from the pool, the ratio of modeled concentration to the level of concern (0.1 PEL) was largest for benzene (40/100 = 0.4) and smallest for methyl ethyl ketone (40/20000 = 0.002). For the saturated soil scenario, the ratio for benzene was 0.02 (2/100) and for methyl ethyl ketone, 0.00001 (2/20000).

3.5 CONCLUSIONS BASED ON MODELING RESULTS

Based on the modeled 8-hour average concentrations given in Table 5, it was concluded that emissions from accidental spills (as large as 7 m by 7 m by 1 cm) could pose a risk to residents at the nearest receptor site (R1). Therefore, the operating procedure for remediation should be to clean up a spill immediately. On the other hand, the modeled data also indicated that emissions from contaminated soil would not pose a risk to anyone outside the site fenceline. Furthermore, these modeled concentrations from the saturated soil scenario were low enough to indicate that there should be no problem in securing the site and terminating monitoring activity at the end of the work day. Emissions from a secured site should be so low as to not pose a problem, except maybe, during inversions. Monitoring only during the 8-hour work day should be sufficient a great majority of the time to protect the residents at the receptor sites, however, the monitoring system design should include provisions for monitoring during non-work hours or evenings when meteorological conditions are conducive to inversions.

Based on the modeled emission rates given in Figures 4 and 5, which show a very short lag time between a spill and resulting high emission rates (and thus high concentrations), the site workers should wear protective clothing while on-site. Also, the monitoring system designed to provide 8-hour average concentrations at the receptor site must be operated over the entire 8-hour work day so that the 8-hour averages will be measured accurately when accidental spills occur. In addition, some form of monitoring that provides real-time or near real-time data should be in operation at the receptor site to monitor for short-term exposure and to allow for timely application of emission control actions at the work site.

SECTION 4.0
SELECTION OF MONITORING INSTRUMENTS

4.1 INTRODUCTION

The purpose of this section is to work through the process of selecting monitoring instruments that will fulfill the requirements of the measurement system design. Personal experience with specific instruments and sample collection techniques and unique features of the subject superfund site will always be factors in the selection process and ultimately in the monitoring system design. The selections made in this section were based on input from individuals, with some experience with the methods, as to the capability of the methods to produce the quality and quantity of data needed to satisfy the stated DQOs. Since the purpose of this document is to illustrate how the DQO process can be applied to this site, discussions of technical strengths and weaknesses of each monitor and sampling technique are minimized so as not to detract from the process itself. To some extent, the instrument selection process and the measurement system design effort had to proceed in parallel since they depend on each other. Details of the measurement system design are given in Section 5.0. The information considered in selecting monitoring instruments is presented in the following paragraphs.

The measurement system design consists of three monitoring strategies. First, modeling data indicated that in the absence of open pools of liquid waste, the probability of the residents at the receptor sites being exposed to VOC concentration levels of concern was very small. Thus, a single screening strategy was chosen as the first element of the monitoring system design. This strategy was designed to provide the RPM/OSC with real-time information on total VOC concentrations near and downwind of the work site to allow timely initiation of emission control procedures when necessary.

The second element selected for the monitoring system design was a refined screening strategy. This strategy will be employed if the results from the screening strategy show that a preset criterion for implementing the refined screening strategy has been exceeded. The objective of the refined screening strategy is to provide the RPM/OSC with real-time or near real-time concentrations of the six indicator compounds near and downwind of the work site.

Since the concentration level of concern is different for each VOC, a knowledge of the individual VOC concentrations provides the RPM/OSC with more information to assess the risk of not initiating emission control actions than is available from the screening results. Also, this refined screening strategy provides total VOC concentrations at the impacted receptor site in real-time to allow for timely initiation of emission control actions and provide information on short-term exposure levels.

When on-site measurements from the screening and/or refined screening strategies exceed preset criteria, a third element of the monitoring system, a quantitative assessment strategy will be employed to provide the RPM/OSC with 8-hour average concentrations of individual VOCs at the receptor sites for that work day.

Procedures for selecting monitoring instrumentation for each of the three monitoring strategies are discussed separately by strategy in the following subsections. The selection process starts with a description of the performance and operational requirements of the monitoring instrument. This is followed by an overview of the commercially available instruments considered for this application. Finally, the instrument and associated apparatus selected for this application are discussed.

4.2 SCREENING STRATEGY

The primary function of the monitoring instrument for the screening strategy is to provide a continuous, real-time indication of VOC concentrations near and downwind of the work site. There are several commercially available VOC monitors that provide real-time data for total VOC concentrations.

4.2.1 Operational and Performance Requirements

The operational requirements and performance capabilities of an instrument for this application are as follows:

- Operate outside year-round.
- Operate continuously over an 8-hour work day without external electrical power.
- Be portable, easily carried by one person.
- Respond to all six indicator compounds.

- Have a detection limit of better than 1 ppm for isobutylene (the calibration gas).
- Be capable of recording the total VOC data over an 8-hour period.
- Not respond to interferences common to Superfund sites including methane, water, carbon dioxide, nitrogen, and oxygen.
- Be capable of visual or audible alarms at preset total VOC concentration levels.

4.2.2 Overview of Commercially Available Instruments

There are a number of manufacturers marketing total VOC monitors. Each manufacturer usually specializes in a monitor with one of two possible detectors: a flame ionization detector (FID) and a photoionization detector (PID). Thus, the first decision in the instrument selection process was to decide on the appropriate detection technique. Table 6 contains a comparison of the two techniques including sensitivity, response time, and drift over 7 hours for the six indicator compounds. As seen in the table, the PID responds to all six compounds with detection limits below the respective levels of concern (0.1 PEL). The FID does not respond to carbon disulfide. Also, a total VOC monitor equipped with a PID does not require a source of hydrogen gas as does a monitor equipped with an FID. The FID hydrogen-burning system requires more controls and a more complicated pneumatic system.

Once the detection technique was selected, recommendations were solicited from individuals with experience using total VOC monitors in the field. One highly recommended instrument that possessed all the capabilities specified in subsection 4.2.1 was reviewed and selected for this application.

4.2.3 Capabilities of Selected Instrument

The instrument chosen for this task was a total VOC-PID monitor with the following capabilities:

- Designed to operate outside in the extremes of weather.
- Designed to operate continuously throughout the 8-hour work day with the use of an additional battery.
- Is portable, easily carried by one person, and easy to operate and maintain.

TABLE 6. COMPARISON OF TOTAL VOC DETECTION TECHNIQUES

	Benzene	Carbon Tetrachloride	Carbon Disulfide	Trichloroethylene	1,1,2 Trichloroethane	Methyl Ethyl Ketone
Photonization Detector						
Sensitivity	200 ppb	1 ppm	300 ppb	200 ppb	1-2 ppm	300 ppb
Response Time	3 sec	3 sec	3 sec	3 sec	3 sec	3 sec
Drift (7 hr)	4%	4%	4%	4%	4%	4%
Flame Ionization Detector						
Sensitivity[a]	1 ppm	10 ppm	NR	2 ppm	10 ppm	2 ppm
Response Time	2 sec	2 sec	---	2 sec	2 sec	2 sec
Drift (7 hr)	10%	10%	---	10%	10%	10%

[a] Response needs to be above the ambient methane response for detection.
NR = no response

- Responds to all six indicator compounds at concentrations below the respective levels of concern.
- Shows a detection limit of 0.1 ppm for isobutylene (the calibration gas).
- Incorporates advanced microprocessor technology for real-time digital or graphic data assessment and built-in data logging capability for storing data, including concentration with time and location.
- Does not respond to methane, water, carbon dioxide, nitrogen, and oxygen.
- Programmed to sound an alarm at predetermined total VOC concentrations.

4.2.4 Purchase and Maintenance Costs

The cost of the selected VOC monitor was $4500, the supplementary field kit was $600, and the battery was $300. Spare parts needed for continuous operation included a lamp ($215), an extra battery ($300), and 5 inlet filters ($25). A calibration source (compressed gas cylinder) of isobutylene cost $500.

4.3 REFINED SCREENING STRATEGY

The refined screening strategy provides the RPM/OSC with near real-time concentrations of the six high risk indicator compounds near the work site and total VOC concentrations at the impacted receptor site. Also, the refined screening strategy will provide information on the appropriateness of the six high risk compounds selected as indicators. This strategy will provide tentative identification of unknown compounds released from the work site, serve to determine when to implement the quantitative assessment strategy, and provide guidance on when to submit the quantitative assessment sample for analysis by GC/MS to identify unknown compounds. This information is used to assess the seriousness of the emissions from the work site.

4.3.1 Operational and Performance Requirements

The instrument for providing total VOC concentrations at the receptor is a total VOC-PID. It was selected for the same reasons discussed in the screening strategy (Section 4.2).

The operational requirements and performance capabilities of an instrument for providing near real-time concentrations of at least the six indicator compounds near the work site are as follows:

- Operate outside year-round.
- Operate continuously over an 8-hour work day without external electrical power.
- Be portable, easily carried by one person.
- Respond to all six indicator compounds.
- Have a detection limit of better than 1 ppm for benzene.
- Be capable of recording the concentrations over an 8-hour work day.
- Have a precision, expressed as a relative standard deviation, of 20% or better for each of the six indicator compounds at their respective levels of concern, and have a negligible bias.

4.3.2 Overview of Commercially Available Instruments

There are a number of manufacturers marketing portable GCs which are equipped with one or more detectors. The four available detection techniques are argon ionizaton detector (AID), photoionization detector (PID), flame ionization detector (FID), and electron capture detector (ECD). Table 7 provides sensitivity estimates interpreted as detection limits, analysis cycles, and precision estimates in reference to the six indicator compounds. As seen in the table, the PID and the AID respond to all six indicator compounds with detection limits below the respective levels of concern (0.1 PEL). The AID and PID provide similar responses for four of the six compounds with the AID having superior sensitivity for the two remaining compounds. At least one of the six compounds result in minimal or no response using the FID and ECD detection techniques.

4.3.3 Capabilities of Selected Instrument

The detection technique chosen for this application is the AID because of its ability to respond to all six indicators. Once the detection technique was selected, recommendations were solicited from individuals with experience using the portable GC-AID in the field. One GC-AID monitor possessing all the required capabilities specified in subsection 4.3.1 was reviewed and selected

TABLE 7. COMPARISON OF GAS CHROMATOGRAPH DETECTION TECHNIQUES

	Benzene	Carbon Tetrachloride	Carbon Disulfide	Trichloroethylene	1,1,2 Trichloroethane	Methyl Ethyl Ketone
AID sensitivity	10 ppb	20 ppb	10 ppb	10 ppb	20 ppb	10 ppb
PID sensitivity	1 ppb	100 ppb	5 ppb	1 ppb	100 ppb	5-10 ppb
FID sensitivity	10 ppm	100 ppm	NR	< 100 ppb	< 100 ppb	20 ppb
ECD sensitivity	NR	1 ppb	150 ppb	2 ppb	< 1 ppb	NR
Analysis Cycle	10 min	10 min	10 min	10 min	10 min	10 min
Precision	10%	10%	10%	10%	10%	10%
Concentration Level of Concern						
0.1 PEL[a]	100 ppb	200 ppb	400 ppb	5 ppm	1 ppm	20 ppm

[a] Permissible Exposure Limit

Note: • NR = no response
• Detection limits are estimated from manufacturer's data and other sources and not determined under field conditions.

for this application. The instrument chosen was a portable GC-AID monitor with the following features:

- Designed to operate outside in the extremes of weather.
- Designed to operate on batteries and continue throughout the 8-hour work day.
- Is portable, easily carried by one person, and easy to operate and maintain.
- Responds to all six indicator compounds at concentrations below the respective levels of concern.
- Shows a detection limit of better than 0.1 ppm for benzene.
- Incorporates advanced microprocessor technology for near real-time data output. Data can be retrieved by either reviewing on a computer screen or connecting the GC-AID to a printer. The computer program provides peak identification of up to at least 9 peaks, calibration information, and concentrations of the 9 peaks.

4.3.4 Purchase and Maintenance Costs

The cost of the selected portable GC-AID, equipped with a modular oven and an external battery, was $20,500. A calibration source and a carrier gas source (two compressed gas cylinders: calibration source @ $3000 and carrier gas at $100) are needed for field operation. Spare parts needed for continuous operation include fittings and columns ($500) and inlet filters ($25).

4.4 QUANTITATIVE ASSESSMENT STRATEGY

The purpose of the quantitative assessment strategy is to document the ambient air 8-hour average concentrations that occurred at the receptors during the work day. Note that the total VOC-PID monitor described in the refined screening strategy provides real-time total VOC concentrations at the receptor site.

4.4.1 Operational and Performance Requirements

The operational requirements and performance capabilities of an instrument for this application include the following:

- It must collect a representative 8-hour sample year-round.
- It must provide data of sufficient quality (precision and bias) for meeting the DQOs.

- It must provide concentration results within 2 to 3 weeks of sampling.
- It must provide speciation of all VOC compounds identified in the liquid waste.

4.4.2 Overview of Commercially Available Instruments

Sample collection can be conducted using either a sorbent or a stainless steel canister. Summa canisters and adsorbent tubes have both been successfully used for ambient air monitoring at superfund sites. Both methods have their strengths, their applications, and their problems. Experienced users of both methods believe that they are capable of producing data of sufficient quality to satisfy the DQOs. For actual application, the selection would probably be based on the personal preference of the user. Adsorbent tube based sampling programs appear to be less tolerant of a lack of experience by the sampling crew and sampling program designer than a canister based sampling program. For this illustration of the DQO process, in this document, canister samplers serve as the selected method of collecting 8-hour VOC samples. (It is realized that there are differences of opinion on the stability of methyl ethyl ketone and carbon disulfide in summa canisters.)

Canister sampling is conducted by one of two methods. One method is where the canister fills with ambient air against a flow restrictor, regulated by the vacuum within the canister. In other words, the canister begins and ends sampling under vacuum. In the laboratory, the sample is pumped from the canister for analysis. The second method is where the canister is filled by using a pump. Once again, there are flow restrictors in-line to maintain a constant flow over the sample period (8 hours). Thus, the canister begins sampling under a vacuum and ends sampling under pressure. In the laboratory, the pressure within the canister is used to deliver a sample to the GC. Recent sampling programs within the EPA have demonstrated this second method to be susceptible to contamination. Canister samplers are available from several manufacturers and can be ordered in either of the configurations described above.

To provide data of sufficient quality to satisfy the DQO, a laboratory GC is required for analysis of the canister samples. A GC with one or more of three detectors or a GC with mass spectrometry will provide the quality of data necessary. The three detectors generally available are PID, FID, and ECD; many times more than one detector would be operated on the same GC (note

the AID has lower detection limits but may not, at this time, be available in most laboratories). The detection techniques are listed in Table 7. As seen in the table, the PID responds to all six indicator compounds with detection limits below the respective levels of concern. For this application, the low detection limits are important since most of the VOC concentrations will be below the levels of concern. At least one of the six compounds provide minimal or no response using the FID or ECD detection techniques.

Since both systems GC/MS and GC-PID with confirmation by FID will reportably produce data of sufficient quality to satisfy the DQOs and have similar costs the selection is based on convenience. Because of a local laboratory equipped with and experienced in the use of GC-PID/FID this becomes the method of choice for this application.

4.4.3 Capabilities of Selected System

The selected system will use evacuated canisters to collect an ambient air sample and use GC-PID with confirmation by FID to analyze the ambient air sample. Ten percent of the samples will be subjected to GC/MS for qualitative confirmation. The primary criterion for subjecting a sample to analysis by GC/MS is an indication by the on-site portable GC-AID monitor that unknown compounds were released from the work site during that work day. These GC/MS analyses will be performed by a laboratory that does not use a perma-pure drier in the GC/MS sampling line because of the potential sample losses of methyl ethyl ketone and carbon disulfide. The canister will begin and end sampling under a vacuum (not using a sample pump) to minimize the potential of contamination. The canister analysis will be conducted by a laboratory with demonstrated experience. Demonstrated experience was documented by participating successfully in the EPA's audit cylinder repository program. Prior to initiating the remediation activities, the laboratory chosen to analyze the canisters will demonstrate capabilities for analysis of at least the six indicator compounds.

The sampling system selected for this application will provide the following:

- A representative 8-hour sample
- A precision of 20% RSD (relative standard deviation) with no overall bias to satisfy the DQOs

- Speciation of all compounds expected to be emitted from the Superfund site.

4.4.4 Purchase, Maintenance, and Analysis Costs

The cost of the selected canister sampler was $5000 and each canister cost $500. Based upon using four canister samplers and thirty-four canisters, the total purchase price would be $37,000. Spare parts should include tubing, ferrels, and valves used to connect the canisters to the samplers. Spare parts costs are estimated to be $500.

Based on 130 canisters being analyzed at $500 each. (See Section 5.4.3 for a breakdown).

SECTION 5.0
MONITORING SYSTEM DESIGN

5.1 GENERAL

The purpose of this section is to design a monitoring system for VOCs in ambient air during the remediation process at this hypothetical Superfund site. One function of this monitoring system is to provide the RPM and/or on-site coordinator (OSC) with data of sufficient quantity and quality to allow for timely initiation of emission control actions. These emission control actions should preclude exposing the subject population to VOC concentrations greater than the levels of concern. This function of the monitoring system will be partially accomplished by a screening strategy that employs a total VOC-PID monitor at the work site to provide real-time data on emissions from the site. In addition, if the screening strategy results show that total VOC concentrations exceed a preset level, then a refined screening strategy is initiated. The refined screening strategy employs two instruments, a portable GC-AID near the work site to provide near real-time concentration values for the six high risk indicator compounds and a total VOC-PID at the receptor site to provide real-time total VOC concentrations. This limited speciation by the portable GC-AID will reveal the presence or absence of the high risk compounds. The presence of one or more of these compounds at preset concentration levels will be reason to alert the RPM/OSC to initiate emission control actions, and, under certain conditions, to shut down the remediation activity. The total VOC concentrations measured at the receptor site will also be used to alert the RPM/OSC if predetermined concentrations are exceeded.

Another important function of the monitoring system is to generate data necessary to preclude the RPM/OSC from unnecessarily slowing or stopping the remediation. This function is fulfilled by using the refined screening strategy. As part of the refined screening strategy the portable GC-AID is deployed to provide compound-specific data on the high risk compounds. For example, if the total VOC-PID monitor at the work site indicates a VOC concentration of 100 ppm, the RPM/OSC may be inclined to stop the remediation activity if, for example, the portable GC-AID indicates that the total 100 ppm is benzene, which has a PEL of 1 ppm. Conversely, the RPM/OSC would not be as

concerned if the total 100 ppm was, for example, methyl ethyl ketone (which has a PEL of 200 ppm). Thus, this function of the monitoring system could be very important in the overall efficiency of the remediation program. Also, results from the portable GC-AID can be used to provide tentative identification of unknown compounds by comparing the observed relative retention time of an unknown peak against relative retention times that had been obtained for the more volatile, non-indicator compounds in Table 2. The other part of the refined screening strategy involves deploying a total VOC-PID monitor at the nearest impacted receptor site. This total VOC-PID monitor at the receptor site will be used to inform the RPM/OSC that VOCs emitted at the work site are reaching the receptor site.

A third function of the monitoring system is to provide information of sufficient quantity and quality to assure the RPM/OSC, decision maker, and residents at the receptor sites that the DQOs were met. This function is fulfilled by the quantitative assessment strategy consisting of an evacuated canister that collects an 8-hour sample at the subject receptor site for subsequent analysis by laboratory GC-PID with FID confirmation. The precision, bias, and speciation capabilities of this procedure indicate that the DQOs will be satisfied for the compounds of interest for this Superfund site. There are differences of opinions on the stability of methyl ethyl ketone and carbon disulfide in canisters. For this illustration it is assumed that they are stable. Recent evaluation tests indicate that at least methyl ethyl ketone can be successfully collected in canisters.

A special characteristic of this site that has influenced the monitoring system design is that the fenceline around the site is lined with a row of full-grown trees, invalidating the customary procedure of monitoring at the fenceline. This, plus the closeness of the receptor sites to the fenceline, means that for a sample to be representative of the ambient air at the receptor, the sample must be collected at or adjacent to the receptor.

Based on the modeling data and to fulfill the three functions described above, three different monitoring strategies are being employed for this project:

- Screening at the work site for total VOC concentrations in real-time.
- Refined screening at the work site for near real-time concentrations of the six indicator compounds and at the receptor site for real-time concentrations of total VOCs.

- Quantitative assessment at the receptor site for integrated 8-hour averages of individual VOCs.

These monitoring strategies will be used together to guide the on-site personnel in applying emission control actions and to document off-site concentrations at the receptor sites.

5.2 SCREENING STRATEGY

Screening is the least costly monitoring strategy, but provides the least amount of information. It does provide real-time data, however, allowing for a quick response to a problem should one occur. Screening is to be employed at the beginning of the project and/or work day and will continue until emissions from the work site result in a measured VOC concentration that exceeds a preset level. The monitoring system selected for screening is a total VOC-PID monitor. This monitor will serve dual roles. It will provide health and safety data and screening data for the potential off-site migration of VOCs emitted from the work site. This system's capabilities are described in Section 4.0. The following subsections discuss this monitoring strategy.

5.2.1 Deployment of the Total VOC-PID Monitor

For the screening strategy, when not in conflict with health and safety monitoring, the total VOC-PID monitor will be positioned on a stable tripod 30 meters downwind of the work site and operated for the 8-hour work day. The monitor will be repositioned at least once an hour if necessary to remain in the plume center directly downwind of the work site. (As needed or when operating in the refined screening level, the total VOC-PID monitor can be used to evaluate upwind concentrations and/or to help the on-site personnel locate the exact emission source at the work site.)

Based on the modeling data, the probability of experiencing VOC concentration levels of concern at any of the receptor sites is very low. Thus, this simple screening strategy may prove to be the only strategy required during the remediation program.

5.2.2 Actions Based on Screening Results

Screening results are available in real-time and are used to alert the on-site personnel to potential problems. Specifically, results from the total VOC-PID monitor based on preset criteria are used to:

- Alert the RPM/OSC that there is an emission source, allowing the source to be located and controlled if necessary;
- Alert the RPM/OSC to check that proper protective clothing is being worn;
- Direct the monitoring crew to initiate refined screening; and
- Direct the RPM/OSC to initiate emission control actions.

5.2.3 Estimated Operating Manpower and Costs

Operation and maintenance of the total VOC-PID monitor is estimated to require 1 FTE. This will consist of calibrating and deploying the monitor at the beginning of each work day. The monitor can then operate unattended until its alarm is activated, except for those times when repositioning is necessary to keep the monitor in the plume centerline and downwind of the work site. The monitor is recalibrated at the end of the work day.

Operating costs, including cost of purchase, replacement parts, and calibration standards as provided by the manufacturer and gas supplier, are as follows:

• Purchase price	$4,500
• Supplementary field kit	$ 600
• Supplementary battery	$ 300
• Extra battery (replacement)	$ 300
• Lamp	$ 215
• Inlet filter	$ 25
• Calibration standard	$ 500
TOTAL	$6,440

5.3 REFINED SCREENING STRATEGY

Refined screening is employed when a potential problem is indicated by the total VOC-PID response. Refined screening is more costly than screening, but it provides some compound-specific information, allowing the RPM/OSC to better evaluate the seriousness of the problem. The portable GC-AID monitor selected for refined screening can be programmed to identify and quantify at least nine compounds. The nine programmed compounds can be changed if

unexpected compounds posing high risk to the resident population are identified during the clean-up process. Initially, the portable GC-AID monitor will be programmed to identify and quantify responses for the six indicator compounds. The total VOC-PID monitor for this strategy is in addition to the one used in the screening strategy. It provides the RPM/OSC real-time data on total VOC concentration at the impacted receptor site.

5.3.1 Deployment of the Portable GC-AID and the Total VOC-PID

Refined screening is conducted with the portable GC-AID monitor positioned 30 meters downwind of the work site. The instrument must be calibrated and ready for operation at any time during the 8-hour work day. It should be capable of being placed on-site and generating data within 15 minutes. The portable GC-AID monitor will be repositioned as necessary, but at least once an hour (while refined screening is in effect) to stay in the plume centerline, directly downwind of the work site. An alternative approach to be considered is to set-up the portable GC-AID in the on-site laboratory and take syringe samples in the field for analysis in the laboratory.

The total VOC-PID will be located at the receptor site with the highest probability of being impacted should a spill occur. This monitor will be used during the work day and after work hours on evenings when meteorological condictions indicate that there could be an inversion.

5.3.2 Actions Based on Refined Screening Results

Concentration values for up to nine compounds are provided by the portable GC-AID approximately once every 10 minutes. These compound-specific data help the RPM/OSC know when to take action and the proper action to take.

Results from the portable GC-AID monitor based on preset criteria are used to:

- Notify the monitoring crew to go to the quantitative assessment strategy, or
- Notify the RPM/OSC to initiate emission control actions.

5.3.3 Estimated Operating Manpower and Costs

Operation and maintenance of the portable GC-AID monitor will require 3/4 FTE. Based on the modeling data, frequent use of the portable GC-AID monitor

is not anticipated. To be able to respond in a timely manner to work-site situations requiring the refined screening strategy, however, the GC-AID monitor will have to be set up and calibrated at the beginning of the work day. It should be placed in a shelter, on a cart, and in a location where it can be easily placed on-site and generating data within 15 minutes when needed. At the end of the work day, the GC-AID monitor will be returned to the on-site laboratory and maintained as necessary to be ready the next day.

Operating costs, including cost of purchase, replacement parts, and calibration standards as provided by the manufacturer and gas supplier, are as follows:

• Purchase price of portable GC-AID equipped with a modular oven, and external battery	$20,500
• Spare parts and filters	525
• Calibration standard and carrier gas for portable GC-AID	$ 3,100
• Purchase price of total VOC-PID (See 5.2.3)	$ 6,440
TOTAL	$30,565

5.4 QUANTITATIVE ASSESSMENT STRATEGY

Quantitative assessment strategy provides more compound-specific information than does refined screening. Results from the quantitative assessment strategy are directly applicable to the receptor site. The monitoring system selected for this level of monitoring includes the use of an evacuated canister to collect the sample and a laboratory GC-PID with FID confirmation for analysis. Also, at least 10% of the canister samples analyzed will be subjected to GC/MS for qualitative confirmation. Specifically, the downwind canister sample(s) collected on days that the portable GC-AID results indicate that unknown compounds were released from the work site will be subjected to GC/MS analysis to identify the unknown compounds.

5.4.1 Deployment of Sampler

For quantitative assessment, one or two receptor areas identified as having the greatest probability of being impacted (i.e., being downwind of the work site) will be instrumented with an evacuated canister sampling system.

Meteorological information will be used to identify the site(s). In areas where two or more receptors are located, a sampling site will be selected so as to be representative of all these clustered receptors. Also, an upwind or parallel site will be selected and instrumented. On a predetermined schedule a co-located sampler will be placed at the receptor site most likely to be impacted as part of the QA program. The samplers must be in place and operating over the 8-hour work day. Results from the portable GC-AID and/or total VOC-PID, combined with meteorological data, will be used to determine if the collected sample will be forwarded to the off-site laboratory for analysis.

5.4.2 Actions Based on Quantitative Assessment Results

Results from analysis of quantitative assessment samples are not available until about two weeks after sample collection. Thus, the data will be used to develop a data base documenting VOC concentration levels experienced at one or more of the receptor sites for various work-site situations. For example, values for the ratio of the concentrations of an indicator compound at the work site and the receptor site for known meteorological and work-site conditions (for example, multiple accidental spills) will be calculated. This information will assist the RPM/OSC in making decisions about the need for emission control actions under similar future work site conditions.

Results of quantitative assessment strategy based on preset criteria will be used to:

- Notify the RPM/OSC that remediation procedures must be changed to reduce emissions if levels of concern are regularly approached or frequently exceeded at one or more receptor sites.
- Notify the RPM/OSC that certain receptor sites must be evacuated before continuing remediation if the levels of concern are regularly exceeded in spite of attempted emission control procedures.
- Provide the RPM/OSC with accurate measures of VOC concentration levels experienced at receptor sites.

5.4.3 Estimated Operating Manpower and Costs

Operation and maintenance of the sample collection activities, and data processing and analysis for this monitoring strategy are estimated to be 1 and 1/4 FTEs. Based on the modeling results, it is anticipated that this level of monitoring will not be required for any extended period of time, except possibly for the two nearest receptor sites. During the remediation program, if

results from the quantitative assessment samples indicate that VOC concentrations do not approach the levels of concern, even on days when spills occurred and the meteorological conditions were extreme, then a decision will be made to discontinue the quantitative assessment strategy. For costing purposes, it is estimated that a maximum of 130 quantitative assessment samples will be analyzed during the remediation program. This includes downwind, upwind, co-located, trip blank, and batch blank (cleaned canisters) samples. At least initially, on-site manpower is required to deploy the three or four samplers before each work day, collect samplers after the work day, and deliver the samples to the nearby commercial laboratory for analysis. It is expected that a great deal of time will be required to review, evaluate, and prepare the data in a form that can easily be interpreted by the RPM/OSC.

The costs associated with the quantitative assessment strategy as provided by equipment manufacturers and a commercial analytical laboratory are as follows:

• Purchase price of canister samplers (4 at $5,000 each)	$ 20,000
• Purchase of 34 canisters at $500 each	$ 25,000
• Canister analysis by GC-PID/FID at $500 each (130 assumed)	$ 65,000
• Canister analysis by GC/MS at $1,000 each (5 assumed)	$ 5,000
TOTAL	$115,000

5.5 CRITERIA FOR EMPLOYING A MONITORING STRATEGY

The criteria for moving from one strategy to another is based on measured VOC concentrations. In the absence of VOC ambient air measurement data, the criteria are purposely set to error on the side of safety. These criteria will be reevaluated and changed if necessary as monitoring data become available. The criteria are discussed for each strategy in the following subsections.

5.5.1 Screening Strategy

The screening strategy is to be employed at the beginning of each work day, unless experience has shown that the remedial activity will result in emission levels that trigger the need for refined screening. The criterion for moving up to the refined screening strategy is any time the total VOC response exceeds 5 ppm for 10 consecutive minutes. This is also the safety criterion for changing from level C to level B dress for on-site workers.

Moving from the refined screening strategy back to the screening strategy is accomplished by simply discontinuing use of the portable GC-AID. The criterion for this move is when the total VOC-PID response has been below 5 ppm for two consecutive hours after the incident that triggered the need for refined screening.

The rationale for the criterion of 5 ppm VOC for 10 consecutive minutes (in addition to it being the safety criterion) follows: benzene, identified as posing the highest risk from the list of compounds in the buried waste, has a PEL of 1 ppm. If, for example, the refined screening results showed the 5 ppm VOC measurement to be 5 ppm benzene, then the RPM/OSC will be notified to initiate emission control actions. Likewise, if the 5 ppm VOC was shown to be 5 ppm methyl ethyl ketone, which has a PEL of 200 ppm, the remediation activity could proceed unimpeded.

5.5.2 Refined Screening Strategy

The refined screening strategy is employed whenever the total VOC-PID response has exceeded 5 ppm for more than 10 consecutive minutes, or at the beginning of the work day if experience indicates a high probability that initiation of remediation will result in screening results greater than 5 ppm.

5.5.3 Quantitative Assessment Strategy

The quantitative assessment strategy is implemented in the event that results from either the on-site portable GC-AID or the total VOC-PID monitor located at the receptor site exceed preset values.

First, results from the portable GC-AID are used to calculate an equivalent exposure (E_m) value for the six indicator compounds as follows:

$$E_m = (C_1 \div PEL_1) + (C_2 \div PEL_2) + (C_3 \div PEL_3) + (C_4 \div PEL_4) + (C_5 \div PEL_5) + (C_6 \div PEL_6)$$

where C is the measured concentration of each indicator compound and the PEL is the respective permissible exposure limit.

For example, suppose the portable GC-AID monitor gave the following results: benzene, 0.4 ppm; trichlorethylene, 5 ppm; carbon tetrachloride, 0.5 ppm; 1,1,2-trichloroethane, 1 ppm; carbon disulfide, 1 ppm; and methyl ethyl ketone, 50 ppm. Combining these concentrations with the respective PELs given in Table 3, Section 2.0 yields the following results:

$$E_m = (0.4 \div 1) + (5 \div 50) + (0.5 \div 2) + (1 \div 10) + (1 \div 4) + (50 \div 200)$$

$$E_m = 0.4 + 0.1 + 0.25 + 0.1 + 0.25 + 0.25$$

$$\boxed{E_m = 1.35}$$

The quantitative assessment strategy is then initiated (that is, one or both of the downwind canister samples (plus the upwind, co-located and trip blank samples) is forwarded to the laboratory for analysis at the end of the 8-hour work day) if the calculated E_m is greater than 1 for 30 minutes or more during the work day.

A second criterion, independent of the portable GC-AID result, is based on total VOC measurements at the receptor site. The quantitative assessment strategy is initiated if the refined screening strategy results show total VOC concentrations greater than 0.5 ppm for 30 minutes or more during the work day.

These criteria are subjective, however; compound concentrations giving an equivalent exposure value greater than 1 occurring 30 meters downwind of the work site may result in measurable levels at the impacted receptor site(s). Also, a total VOC concentration of 0.5 ppm, corrected for background levels, signal the need for application of emissions control actions at the work site.

The reason for having two criteria, one based on total VOC and one on compound-specific results, is that the total VOC concentration may represent compounds other than the six indicator compounds. The quantitative assessment strategy would identify and quantify all VOCs present at or above detection limit concentrations at the receptor site.

5.6 CRITERIA FOR APPLYING EMISSION CONTROL ACTIONS

5.6.1 Screening Strategy

Criteria for taking actions based on screening strategy results follow:

- If the total VOC-PID response is 5 ppm or greater for 10 successive minutes, alert the RPM/OSC that there is an emission source so that the source may be located and controlled as necessary.
- If the total VOC-PID response is 5 ppm or greater for 10 successive minutes, alert the RPM/OSC to check that proper protective clothing is being worn.
- If the total VOC-PID response is 200 ppm or greater for 10 successive minutes, alert the RPM/OSC that emissions must be reduced within the next 30 minutes or halt the remediation activity. (This applies only if the monitoring staff for some reason has been unable to initiate the refined screening strategy in this time period.)

The rationale for the criterion of 5 ppm total VOC is that benzene could account for the major portion of the VOC measurement. Benzene has a short-term exposure limit (STEL) of 5 ppm; thus, the on-site workers would be alerted to wear the proper protective clothing. Also, a potential 5 ppm concentration of benzene 30 meters downwind of the work site may result in a concentration near the level of concern (100 ppb) at one of the receptor sites.

The rationale for the criterion of 200 ppm for 10 successive minutes is that on-site VOC concentrations at this level will probably result in measurable VOC concentrations off-site.

5.6.2 Refined Screening Strategy

The compound-specific information provided by the portable GC-AID monitor is used to guard against allowing one or more of the high risk compounds to reach the receptor site at concentration levels near one tenth of their respective PELs.

There are two criteria for intiating emissions control actions based on refined screening data. The two should be evaluated separately, that is action must be taken should either one be exceeded. The criterion for emission control actions follows:

- The RPM/OSC is notified that emissions must be reduced within 30 minutes or remediation will have to be halted if the portable GC-AID monitor response results in a calculated E_m greater than 1 for 10 successive minutes (see the example calculation in subsection 5.5.3).

- The RPM/OSC is notified that emissions must be reduced within 30 minutes or remediation will have to be halted if the total VOC-PID monitor at the receptor site shows a concentration of 0.5 ppm or greater for 10 successive minutes.

The rationale for the criterion of $E_m \geq 1$ for 10 successive minutes is that one or more of the six indicator compounds could be present at concentrations near their respective PEL which could result in receptor site concentrations near the levels of concern. A total VOC concentration of 0.5 ppm at the receptor site is one tenth of the work site criterion of 5 ppm for moving from level C to level B protective clothing. This is the same rational used for establishing the level of concern at one tenth of the PEL.

5.6.3 Quantitative Assessment Strategy

Quantitative assessment results directly estimate the health risks experienced by residents at the receptor sites. Thus, these results are used by the RPM/OSC to assess when the remediation process being used needs to be changed so that emissions are reduced.

Criteria for taking action based on quantitative assessment strategy results follow:

- The RPM/OSC is notified that remediation procedures must be changed to reduce emissions if any compound identified routinely approaches or exceeds 0.1 PEL, or that the remediation activity must be halted.

- The RPM/OSC is notified that a certain receptor site must be evacuated during the 8-hour work day when meteorological information indicates that it will be in the plume's path and if results have shown one or more compounds to exceed 0.2 PEL under similar meteorological conditions. Otherwise, the remediation activity must be halted.

These above criteria of 0.1 PEL and 0.2 PEL are used here because they are the concentration levels of concern (0.1 PEL) and the concentration level at which the decision maker stated that the monitoring system should be such that the probability of a false negative is no greater than 1 percent.

5.7 ESTIMATED TOTAL LABOR AND COST

In Stage 1 of the DQO the following resources were made available for this ambient air monitoring effort:

- A mobile laboratory to be placed on-site for the duration of the cleanup operation.

- Equipment necessary for cleaning the summa canisters in the on-site laboratory.
- Two monitoring technicians to be dedicated to this air monitoring effort (i.e., 2 FTEs).

The monitoring effort is estimated to require a total work force of 3 FTEs. Thus, one FTE will be required in addition to the two provided by the ESD. It is important to not over-commit the on-site workers because concentrated monitoring activities could occur at any time and the monitoring staff needs to be prepared. The three monitoring personnel will probably have to stagger their shifts in order to fully service the three monitoring systems before and after the work day. That is, the two total VOC-PID monitors and the portable GC-AID must be calibrated before and after each work day. Also, the canisters must be deployed and the samplers set to take a sample spanning the 8-hour work day. Costs have been estimated for each monitoring strategy and are based on the assumption that the refined screening and quantitative assessment strategies will be required infrequently.

Individual costs estimates listed below are only for illustrating the process. The individual item costs are believed to be reasonable but they do not represent actual quotes from manufacturers or contractors nor is the listing presented as a comprehensive list.

Project Planning

• DQO Package - Sampling and analysis plan - Quality assurance project plan - Summary work plan	$75,000
Sub Total	$75,000

Manpower

• One technician (1 FTE) (estimated @ 2,500/week for 52 weeks this includes per deim, overtime, etc.)	$130,000
	$130,000

Screening Strategy Costs

• purchase price of total VOC-PID monitor	$ 4,500
• supplementary field kit	600
• supplementary battery	300
• replacement battery	300
• replacement lamp	215
• inlet filters (5)	25
• calibration standard	500
Sub-Total	$ 6,440

Refined Screening Strategy Costs

• purchase price of portable GC-AID monitor	$20,500
• spare parts and filters	525
• calibration standard and carrier gas for portable GC-AID	3,100
• purchase price of total VOC-PID monitor and needed supplies	6,440
Sub-Total	$30,565

Quantitative Assessment Strategy costs

• purchase price of canister sampler (4)	$ 20,000
• purchase price of 34 canisters	25,000
• canister analysis by GC- PID/FID $500 per sample (130)	65,000
• canister analysis by GC/MS at $1,000 each (5 assumed)	5,000
Sub-Total	$115,000
GRAND TOTAL	$357,005

This total estimated cost greatly exceeds the $50,000 that the decision maker has reported as being available for this effort. Some of the monitors or other equipment such as canisters may be available from the ESD. If so, this could reduce the costs but probably not nearly to the level of available funds. If all the monitors and supplies must be purchased, the possibility of obtaining the total $357,000 will be investigated.

SECTION 6.0
ERROR ANALYSIS FOR COMPLIANCE WITH DQOs

The purpose of this section is to show that the monitoring system design will satisfy the stated DQOs. The DQOs specified by the decision maker and presented in subsection 1.2 of this document are compound-specific and apply to the compound concentrations occurring at the receptor sites.

One aspect of satisfying the DQOs is that a valid sample is collected for the receptor site experiencing compound concentrations near the levels of concern. The criteria for locating the sampling systems at the beginning of each work day are based on meteorological data; the two receptor site areas most likely to be impacted by the work-site plume, should a spill occur, are instrumented each day. Based on the locations of the receptor areas (see Figure 1), the likelihood of not instrumenting the area that will be impacted most by the work-site plume is very small. Also, the decision to submit the collected sample for analysis is dependent on results from screening or refined screening that indicate on-site concentrations above predetermined values. Since the work site is a below- ground-level source with no effective plume rise, it appears highly unlikely that concentration levels of concern will occur at receptor sites and not first be detected by the on-site screening or refined screening procedures. Thus, the decision to submit the canister sample for analysis will be a correct one.

The evacuated canister/laboratory GC-PID system selected for quantitative assessment strategy was evaluated for its potential to satisfy the DQOs. It should be pointed out here that during conduct of the project, adequate QC/QA procedures must be carried out to assure the decision maker and/or RPM that the measurement system is producing data of acceptable quality.

Salient features of this measurement system that influence data quality include, but may not be limited to, the following:

- The canister sampler is located at or near the receptor of interest; that is, there is no error due to spatial variability.
- The canister sampler collects the 8-hour sample at a constant flow rate; that is, there is no error in the 8-hour average due to temporal variability.
- The method is compound-specific for the compounds of concern.

- The scientists experienced with the method provided an overall precision estimate for sample collection and analysis, expressed as a relative standard deviation (RSD) of 20%.

- The system is reported to have no overall bias across the compounds of interest.

Compound-specific data quality objectives were established at three concentrations: 0.5, 1.5, and 2.0 times the level of concern (the level of concern is 1/10 of the permissible exposure limit). An error analysis was performed for one compound, benzene. The permissible exposure limit (PEL) for benzene is 1000 ppb; thus, the level of concern is 100 ppb. The detection limit for benzene is 1 ppb, well below the level of concern.

Following are the data quality objectives and the results of the error analysis, using benzene as an example:

1. "At a true average concentration of 0.5 times the level of concern, the probability of a positive finding should be limited to less than 10%."

   For benzene, 0.5 times the level of concern is 50 ppb. At this concentration, the standard deviation is expected to be 20% of 50 ppb, or 10 ppb. Figure 6 shows a normal distribution having a mean of 50 and a standard deviation of 10. Virtually all of the area beneath the curve is to the left of 100, showing that the probability of finding a measured value above 100 ppb is practically zero when the true concentration is 50 ppb. This is a far better (smaller) error rate than the objective, 10%. Thus, this DQO should be satisfied.

2. "When the true average concentration is 1.5 times the level of concern, the probability of a negative finding should be limited to less than 5%."

   For benzene, 1.5 times the level of concern is 150 ppb. At this concentration, the standard deviation is expected to be 20% of 150 ppb, or 30 ppb. Figure 7 shows a normal distribution having a mean of 150 and standard deviation of 30. The hatched area below the curve and to the left of 100 ppb is the probability of a negative finding when the true concentration is 150 ppb. The figure shows that the probability of finding a measured value below 100 ppb is very near our 5% objective. In fact, the probability is 4.8%. Thus, the DQO should be satisfied as long as the precision, expressed as the relative standard deviation, is not much greater than 20%.

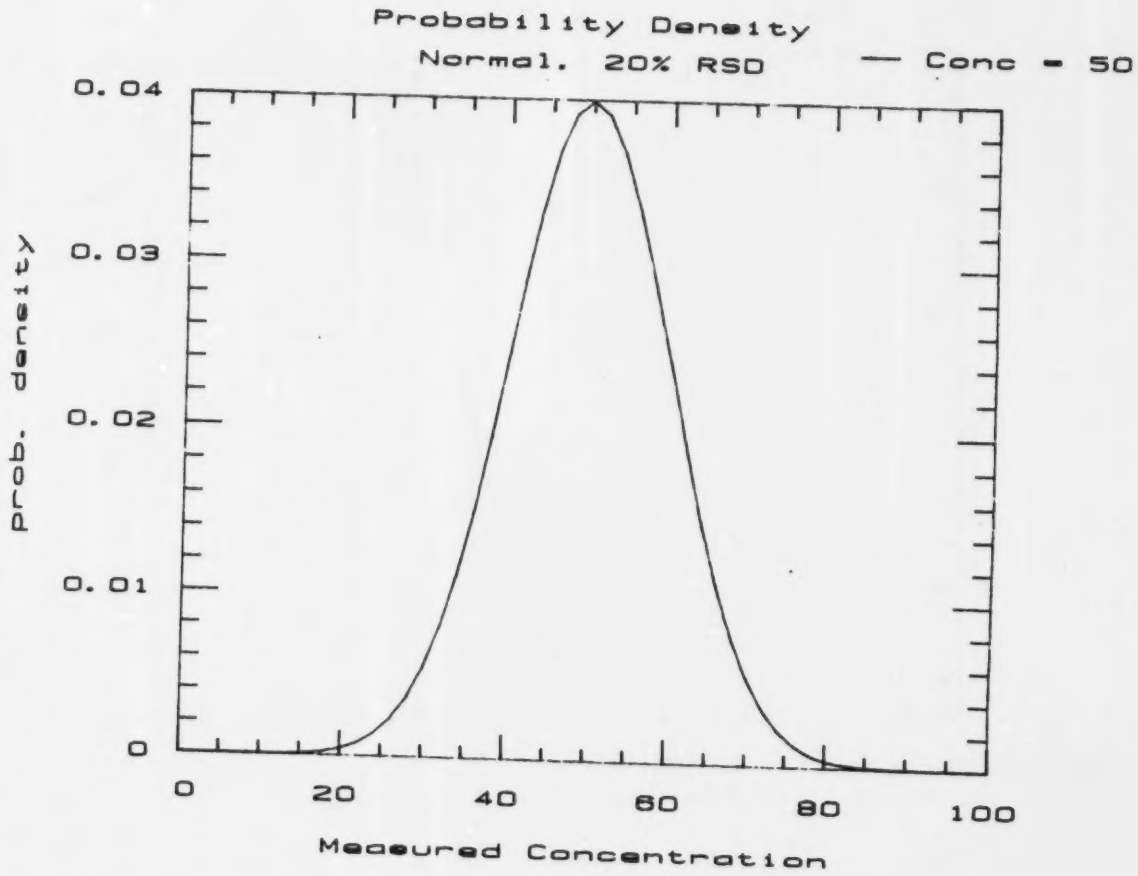

Figure 6. Illustration of the probability of a false positive error when the true concentration is 50 ppb and the concentration of concern is 100 ppb.

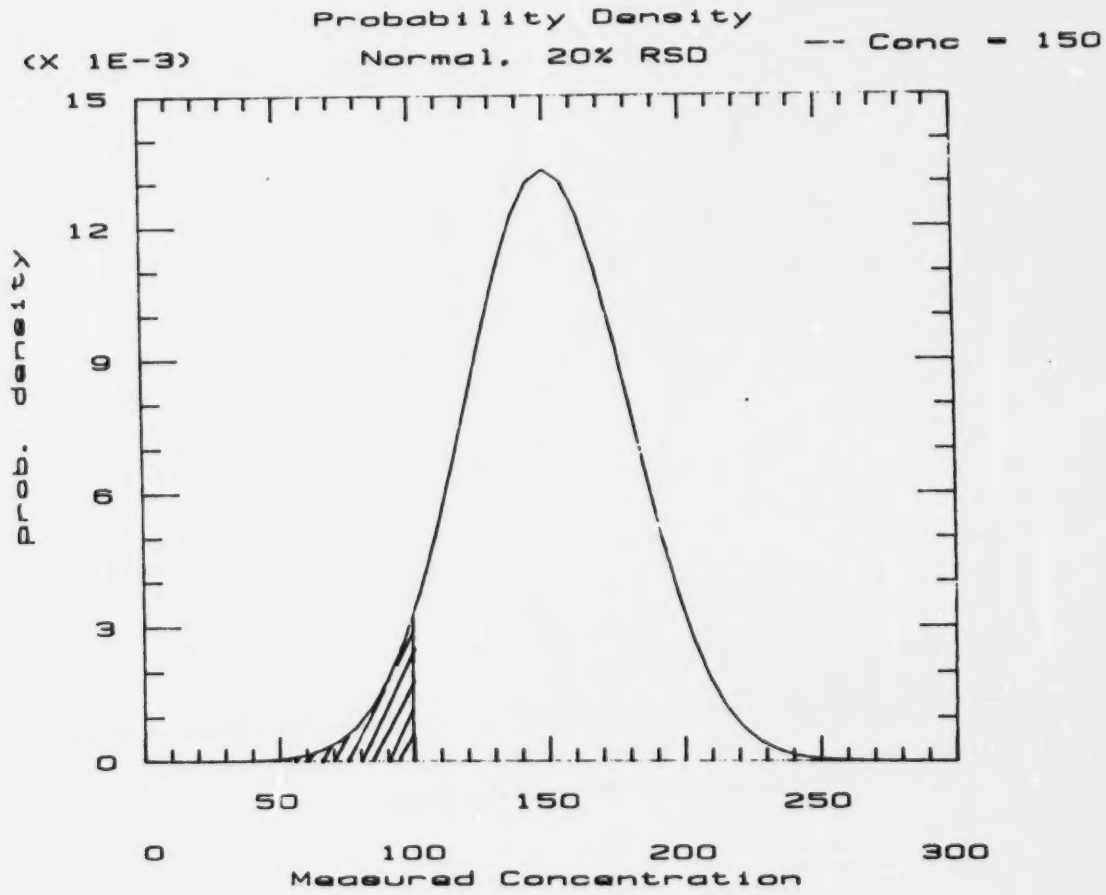

Figure 7. Illustration of the probability of a false negative error when the true concentration is 150 ppb and the concentration of concern is 100 ppb.

3. "When the true average concentration is 2 times the level of concern, the probability of a negative finding should be limited to less than 1%."

   For benzene, 2 times the level of concern is 200 ppb. At this concentration, the standard deviation is expected to be 20% of 200 ppb, or 40 ppb. Figure 8 shows a normal distribution having a mean of 200 and a standard deviation of 40. The area under the curve and to the left of 100 ppb is the probability of a negative finding, given that the true concentration is 200 ppb. The figure shows that the probability of finding a measured value below 100 ppb is very small. This probability is 0.62%, which is better than the acceptable probability of 1%.

Because the same precision (20% RSD) or better is estimated for each of the compounds of concern, identical results would be realized for each of the other compounds if subjected to the above error analysis. These results show that a precision of 20% for sampling and analysis represents the limit of imprecision that will satisfy the DQOs. If the precision of the monitoring system is in fact 20% RSD then extreme care must be exercised to identify and eliminate or quantify and adjust for biases. In this project a negative bias would increase the probability of a false negative error, meaning that an exposure of the public to concentrations in excess of the level of concern could go undetected.

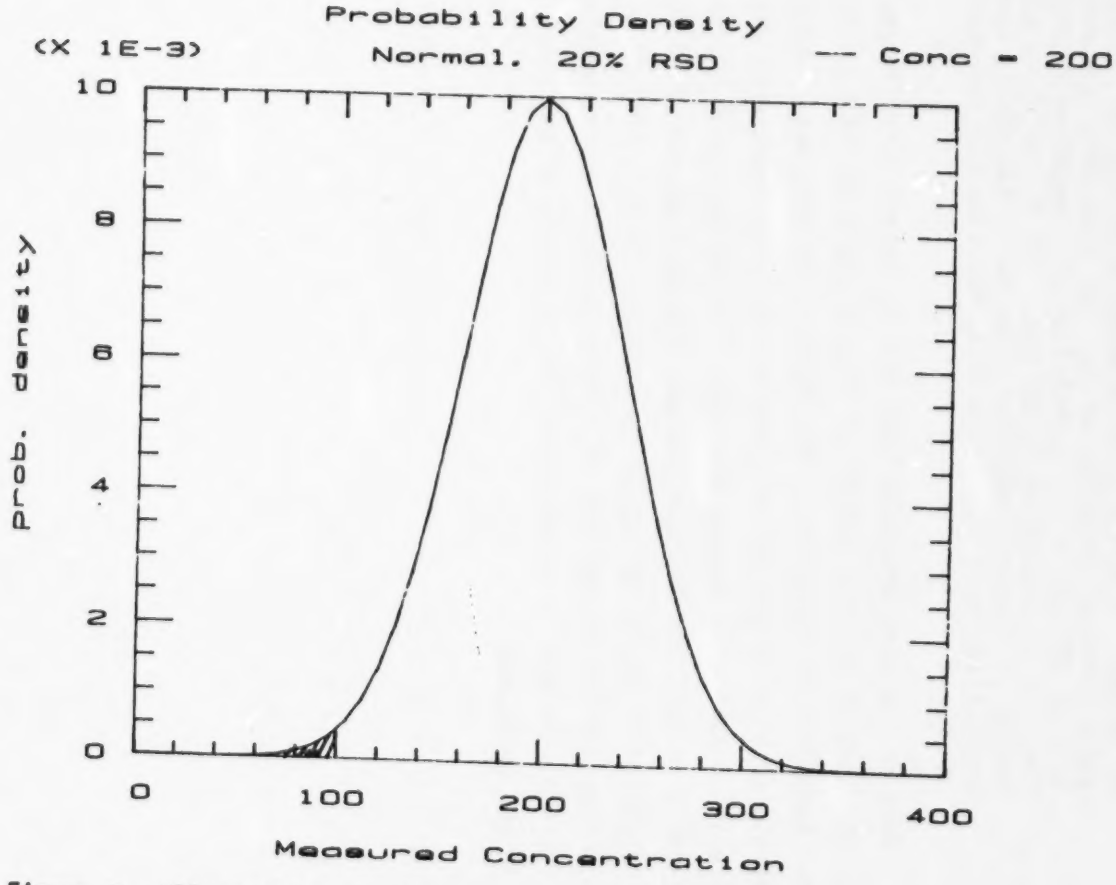

Figure 8. Illustration of the probability of a false negative error when the true concentration is 200 ppb and the concentration of concern is 100 ppb.

SECTION 7.0
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